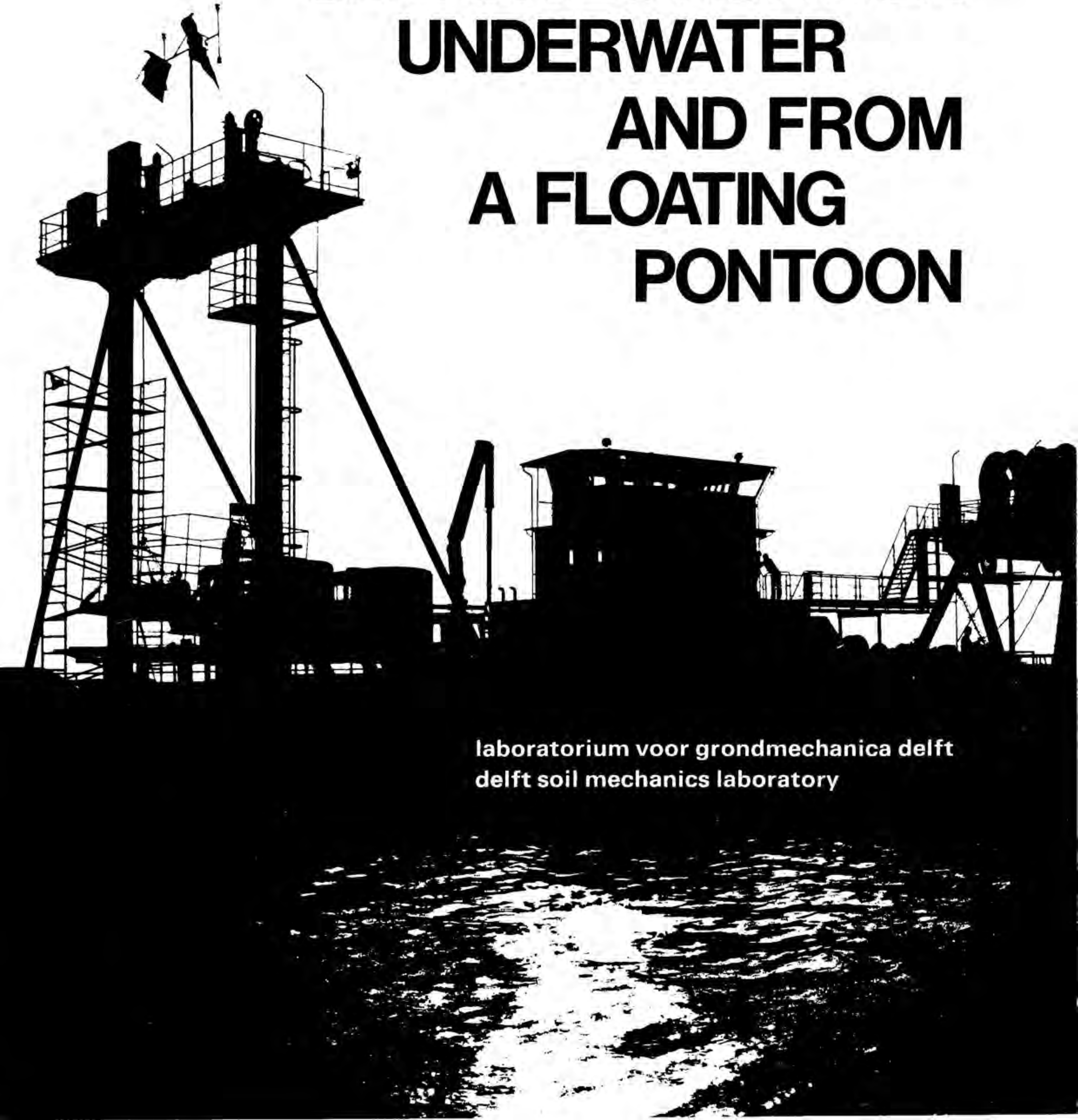
SITE INVESTIGATION UNDERWATER AND FROM A FLOATING PONTOON



laboratorium voor grondmechanica delft
delft soil mechanics laboratory

Site investigation underwater and from a floating pontoon

(Ing. J. Vermeiden)

Introduction

After the publication of an article on the subject in 'LGM-Mededelingen', Part VI. No. 1, of July 1961, the cone penetration testing method for the exploration of subsoil conditions for structures which have to be built wholly or partly in water has undergone further developments.
Especially a large-scale project such as the Eastern Scheldt closure works, and more in particular those investigations which have to be carried out in the closure gaps, have greatly stimulated these developments.
The existing pontoons for cone penetration testing and exploratory sampling boring operations were found to be rather unsuitable as regards size for working under the Eastern Scheldt conditions. They could be used only in favourable weather, which resulted in a low output.
The anchorage facilities were likewise inadequate to cope with conditions encountered on the Eastern Scheldt. A stringent requirement was that no anchors were allowed to be dropped on revetment works already installed on the seabed to prevent scour.
For the purpose of large-scale soil investigations a pontoon was made available by the contractors' consortium Dijksbouw Oosterschelde (DOSBOUW). With dimensions of 78 m by 40 m (Fig. 1), this pontoon had been built for laying factory-made stone revetment mats on the bed of the Eastern Scheldt; these activities had, however, been postponed indefinitely.
The size of this pontoon and its anchorage equipment provide sufficient safeguards to work under less favourable weather conditions.

Remarkable results have been obtained with the aid of this large-size equipment in conjunction with adaptation and improvement of the existing cone-penetration testing and boring techniques. Meanwhile further developments have been taken in hand. The concept of carrying out soil investigation from a manned submersible working chamber has become reality.

Fig. 1 DOS-pontoon with two cone penetration testing/boring rigs.

Experiments have revealed that, using the submersible working chamber, cone penetration tests can be performed in which considerably greater depths and higher penetration forces are possible. Continuous sampling has also been taken in hand. The proven success of the cone-penetration testing and boring equipment, together with the new development of the submersible working chamber, have led to the decision to build a new geotechnical pontoon. All experience gained with the pontoon depicted in Fig. 1 has, of course, been incorporated in the design.

Design and construction of the new geotechnical pontoon

In May 1977 the Delta Service of the Dutch Ministry of Transport, Waterways and Communications commissioned DOSBOUW to build this new pontoon, which would make it possible to carry out soilmechanical investigation from the water surface or from the sea bottom by means of a manned submersible working chamber. In designing the pontoon, the starting point was that both the cone penetration testing and boring equipment and the submersible working chamber would each take up a separate place on the vessel. At the back of the vessel, an open well of 7 x 7 m has been created. Above this well is a 12 m high portal, between which the cone penetration testing and boring equipment is built up. Tide plus working space above the working platform were factors in determining this height. At the front, a centre well of 7 x 7 m has been constructed for launching the submersible working chamber. A centre well has the advantage that the submersible working chamber can easily be approached from all directions and that more benefit can be derived from the working space.
Over the centre well, a heavy four-legged derrick has been installed for lowering the 700 kN (70 tf) submersible working chamber. On the platform over the derrick are two winding devices, one of which is intended for the umbilical through which air conditioning of the submersible working chamber takes place and the communication signals are transmitted; the other winding device is intended for a 380 V electric feeder cable for the hydraulic pressure unit.

In the deck house, on the port side, on deck level, is the engine room for the energy required for the entire vessel. The overlying compartment forms the crew quarters; the second floor is the central control room of the pontoon. From here all deck-mounted winches are operated, including the adjustment of both swell motion

Fig. 2 View of the cone penetration testing and boring equipment.

compensators of the cone penetration testing and boring equipment. The winding devices of the umbilical and the electric feeder cable of the submersible working chamber are also operated from this central control room.
Raising and lowering of the working platform and also the operation of the cone penetration testing and boring equipment takes place from the platform itself.
The hoisting winches for the kentledge blocks of the cone penetration testing equipment and of the submersible working chamber maintain a constant pull on the steel wires when they lie on the bottom.
This also holds for the winding devices of the umbilical and the electric feeder cable of the submersible working chamber.

Fig. 3 View of the launching gear of the submersible working chamber.

Figure 4 shows a side view, the lay-out of the deck and the rear view of the pontoon.
The rear view also shows the cone penetration testing and boring equipment. The legend of the drawing shows the main specifications of the pontoon. Legends clarify further details as much as possible so that a detailed description is not necessary.

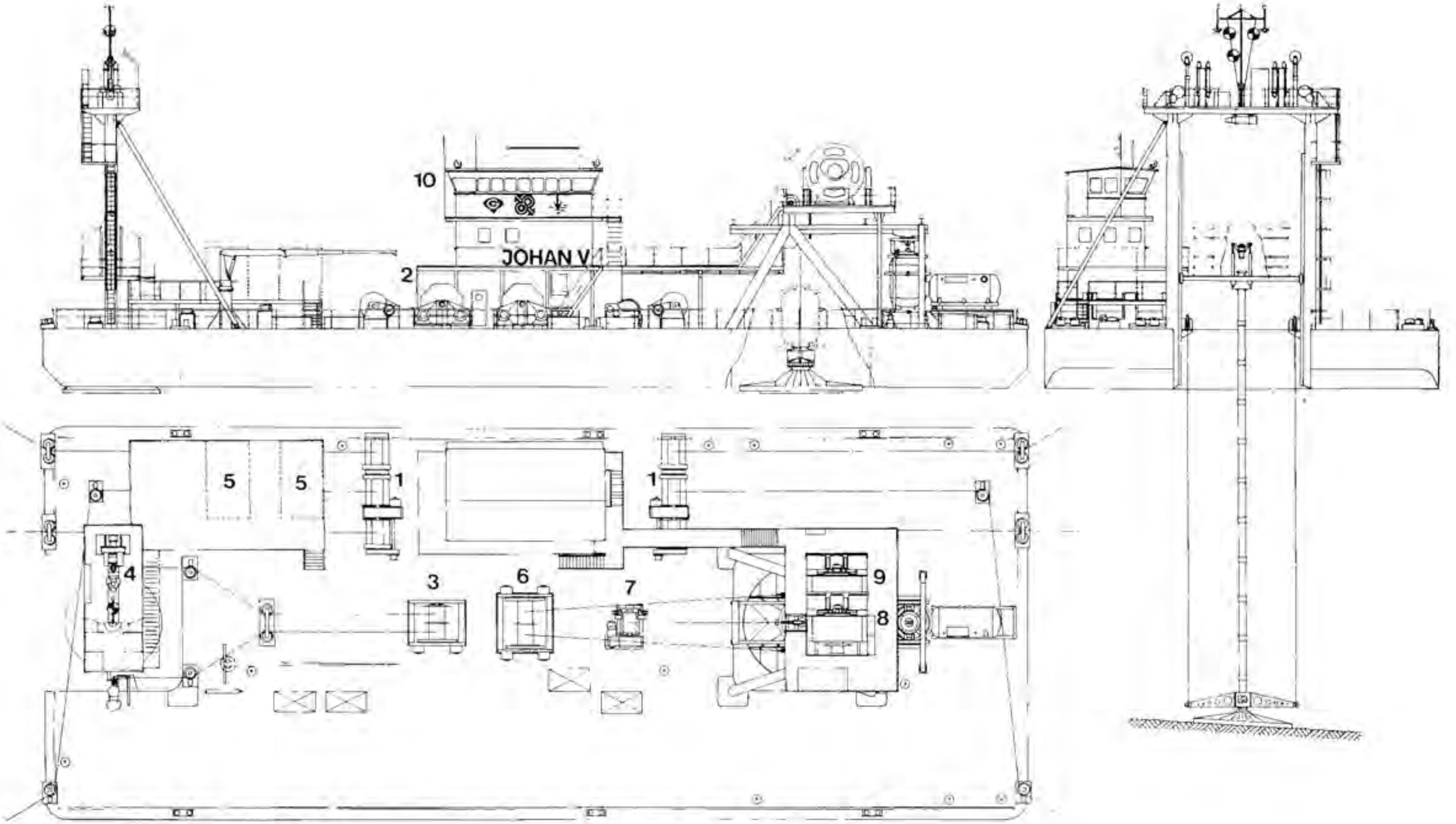


Fig. 4

LEGEND

Main dimension pontoon 50 x 20 x 3 m

1 Anchor winches
2 Engine room
3 Main winch kentledge block cone penetration testing, sampling and drilling equipment
4 Swell motion compensators
5 Registration cabins
6 Main winch kentledge block of submersible working chamber
7 Winch submersible working chamber
8 Winding device umbilical
9 Winding device electrical feeder cable
10 Central control room

The principle of the cone penetration testing and boring equipment

A 400 kN (40 tf) kentledge block is lowered on to the seabed. During the lowering of the kentledge block, a stabilising tube with an internal diameter of 200 mm is built up in 2 m sections from the working platform. The tube sections are threaded. The lowermost stabilising tube is attached to the kentledge block by means of an universal joint. During this lowering operation the working platform hangs on 2 wire ropes each of which is connected to an electrically driven winch, via a swell motion compensator. The winches and swell motion compensators are mounted on the traverse of the large portal.

As soon as the kentledge block is resting on the seabed, the working platform is mounted on the part of the stabilising tube projecting above water. Subsequently the swell motion compensators are put into operation. Together they pull at the entire structure at a constant force of 80 kN (8 tf), via the platform. The working platform is vertically guided by the colums of the portal. This construction is entirely independent of the movements of the pontoon as a result of tide and wave action.

The kentledge block

To resist the reaction force needed for thrusting the penetrometer tubes into ground, a dead weight of approx. 200 kN (20 tf) is needed, while the borehole casings require approx 300 kN (30 tf) for the same purpose. As a result of the swell motion compensators, a constant pull of 2 x 40 kN ((2 x 4 tf) is exerted on the kentledge block. To provide the necessary resistance to horizontal current forces, the contact pressure between the kentledge block and the seabed must be not less than 20 kN (2 tf). On the basis of these figures, a required, underwater weight of 400 kN (40 tf) is arrived at for the block.

In shape it somewhat resembles an inverted saucer. Practical experience has shown that the edge of such an obstacle on the seabed should be as thin as possible to minimise scour due to current, as a result of which the stability of the kentledge block could be endangered.

To meet this requirement and accommodate the necessary quantity of ballasting lead, it had to be given a diameter of 5 m (see Fig. 5).

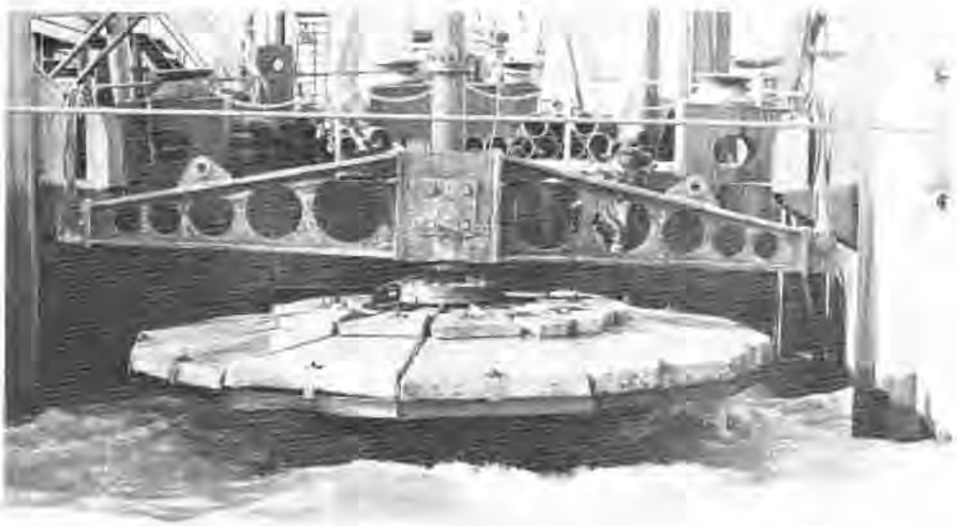


Fig. 5 Kentledge block

The kentledge block is 0.25 m high at its edge and 0.70 m at its centre. The twelve slabs of lead are in the form of a sector a circle and weigh 30 kN (3 tf) each. They are supported on a steel frame with radial members converging on a central tube to which the equalizer and universal mounting are fitted.
The universal fitting can accommodate up to 8° augular movement in relation to the vertical. In the case of sloping bottoms, no additional bending in the stabilizing tube is produced.

Cone penetration testing

Cone penetration tests are carried out from the working platform (3 x 5 m) by means of a hydraulic 20 t penetrometer apparatus. Buckling of the penetrometer tubes in the 200 mm wide stabilising tube is prevented by means of a 40 mm I.D. centering tube installed inside the latter. This centering tube is provided with so-called centring brachets and is built up of 2 m long sections. The 36 mm penetrometer tube runs through this centring tube. Cone penetration testing is only carried out with an electric cone, whether or not provided with a friction sleeve.
Registration takes place in one of the deck-mounted registration cabins. The quantities to be measured (cone and friction resistance) are read off with a digital strain gauge.
Continuous registration is likewise possible.

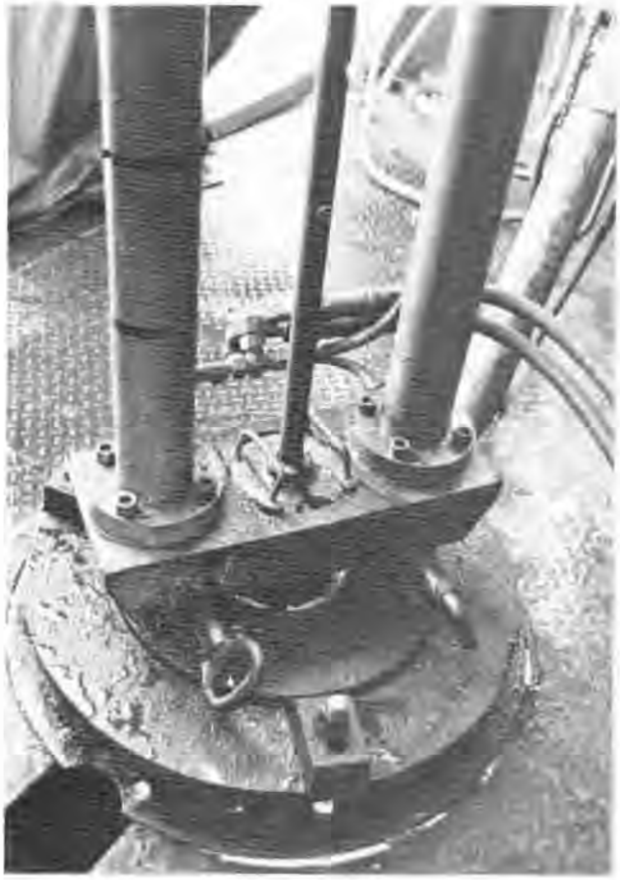


Fig. 6
Carrying out a cone-penetration test.

Boring procedure

Borings are also performed from the same working platform. With the aid of an electric winch a casing consisting of 2 m long sections is lowered from the centre of the platform. On touching the bottom of the water the casing penetrates some distance into the soil under its own weight.

Mounted on the platform on each side of its centre are two hydraulic jacks with a net stroke length of 1.20 m. The jacks derive their reaction from the main girders of the platform and are coupled across the top by means of a bridging member provided with a round hole in the middle of approximately 190 mm diameter. The jacks are powered by the hydraulic equipment of the cone penetrometer apparatus which, when not in operation, is temporarily accommodated at one corner of the platform. Further penetration of the 180 mm diameter casing to its final depth into the seabed is done with the aid of specially designed push-pull device, the tube now being extended section by section in lengths of 1 m.
Normally, so-called Ackermann borings are carried out, i.e. a sample 0.35 m in length is taken from the soil below the casing. The casing is then thrust 0.35 m deeper into the ground and the soil in it is removed with the aid of a shell. These operations are repeated continuously until the borehole has reached its desired final depth.

Fig. 7 Carrying out a boring.

Borings with the 66 mm diameter continuous sampling apparatus have also been successfully carried out. Most borings of this type are performed in two stages. They require the installation of an extra casing of 140 mm internal diameter in order to prevent buckling of the extension tubes (110 mm external diameter). Under such circumstances the 66 mm continuous sampling operation is more time-consuming than an Ackermann boring, but it can claim to achieve optimum quality.

Special measurements

In principle, any method of soil investigation applied on land can also be applied with the aid of the cone penetration testing and boring equipment. The complexity of the Eastern Scheldt closure project in its soil-mechanical aspects also necessitates various special measurements, these being more particularly: density measurements in situ, permeability measurements and pressuremeter tests. All these measurements and tests were performed with the equipment of improved design as described, and in many cases extended down to considerable depths.

The submersible working chamber

As stated in the introduction to this brochure, the submersible working chamber has come to stay on the new geotechnical pontoon on account of the positive test results in the field of cone penetration testing and boring. A point not to be neglected is that cone penetration testing, boring and also density meassurements can be carried out more rapidly and cheaply, despite the higher operating costs. Another aspect is that the cone penetration testing and boring equipment has its limitation with regard to water depth. At a water depth of more than 50 m, utilisation of the equipment is risky. At a water depth of 50 m and more, the wave height will probably determine the safety of people working on the platform. We would like to mention that at wind force 7 work went on in the Eastern Scheldt with the equipment.

In connection with the above, it is obvious that for greater water depths the submersible working chamber is the appropriate apparatus for soil-mechanical exploration of the sea bottom, in particular for offshore structures.
The submersible working chamber in operation has a built-in hydraulic thrusting apparatus with a pressure capacity of 600 kN (60 tf) and a stroke length of 1.05 m. It has been built to Lloyds standards and can operate up to 200 m water depth. For further particulars and details, reference is made to the brochure 'The submersible working chamber'.

Cone penetration testing from the submersible working chamber

If cone penetration tests or density measurements are to be performed, the electrical penetrometer cone with two penetrometer tube sections connected to it are first placed in the eruption sealing passage, before the submersible working chamber is lowered. The rest of the extension tubes, with the electric cable threaded through them in advance, lie in a rack on the bottom of the submersible working chamber. The hydraulic jack or other equipment is operated by the men in the chamber. The results of the measurements are transmitted through the signalling cable to the vessel, where they are either recorded or obtained as digital readings.

In density measurements the operation of measuring the specific electrical resistance of the soil and pore water together is not very different from that required for carrying out a cone penetration test. On the other hand, measuring the specific resistance of the pore water alone, likewise associated with density measurements, may take as much as 8-10 hours. The crew of the submersible working chamber can be relieved halfway through this measuring operation. For this purpose the pressure inside the chamber is increased until it is equal to the surrounding water pressure. The chamber is then disconnected from the base plate and is raised above water by means of the lifting eye. The two thick steel wire ropes again serve as guides in this manipulation. This is the reason why a constant tension must be maintained on these wires. After two relief crew men have got in, the chamber is lowered again and locked to the base plate, the pressure in it is reduced to atmospheric pressure, and the measurement is continued.

Continuous boring

Operations with the continuous sampling apparatus are somewhat more complex than cone penetration testing and similar activities. The air pressure inside the submersible working chamber has to be raised to equalise the outside pressure corresponding to the depth of water. The air is supplied from the compressor installed in the engine room, through the umbilical cord. The crew of the chamber have to perform all the actions that also have to be performed when boring is done

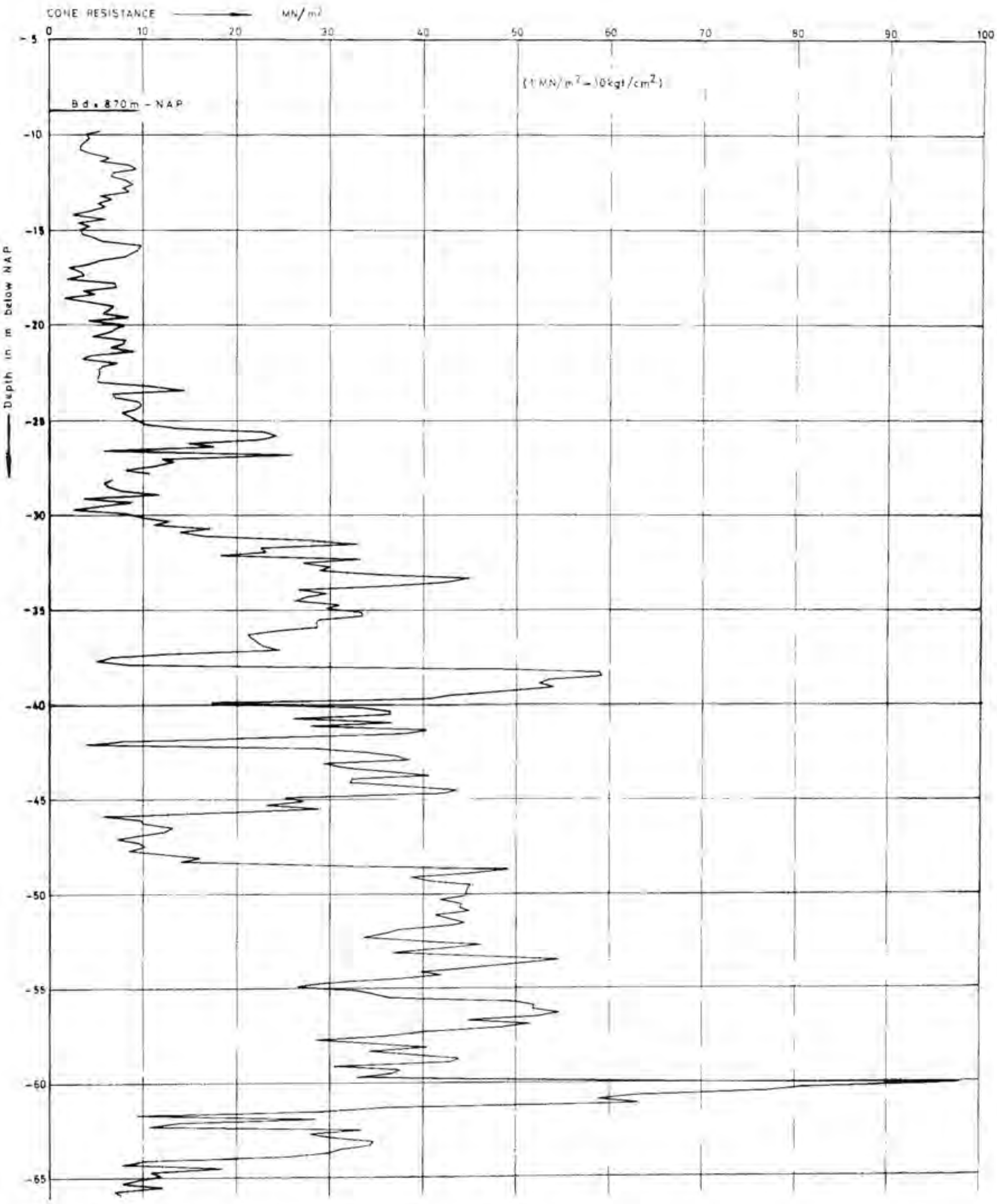


Fig. 8 Cone penetration testing in the Eastern Scheldt.

in the normal way on land, but they now have to work under this increased air pressure. The operations are monitored from the surface, and instructions to the chamber crew can be given from there.

On completion of the boring, the chamber and base plate are raised above water and the crew members transfer to the decompression chamber which has meanwhile been attached to the submersible working chamber. The pressure in the decompression chamber is initially the same as that under which the men worked and is gradually reduced – at a certain rate, depending on the depth at which they worked and the length of time they spent there – to normal atmospheric pressure.

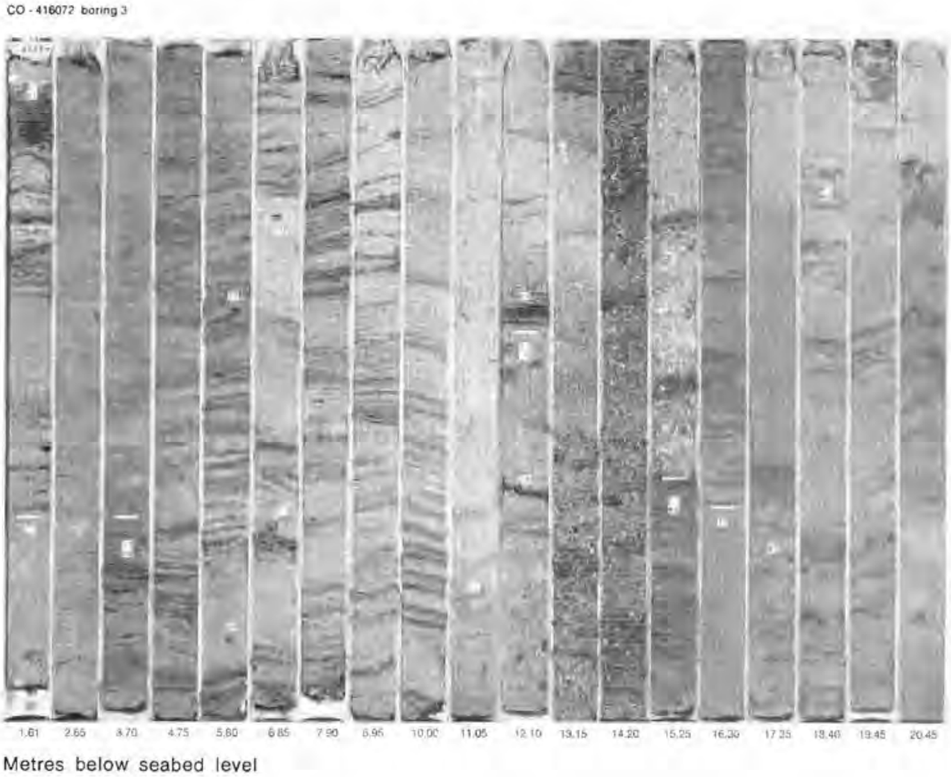


Fig. 9 Boring in the Eastern Scheldt.

Acknowledgements

The development and construction of this new geotechnical pontoons are the result of good co-operation between the Delta Service of the Ministry of Transport, Waterways and Communications, the contractors' consortium Dijksbouw Oosterschelde (DOSBOUW), the diving firm Vriens b.v. at Bergen op Zoom and the Delft Soil Mechanics Laboratory. This joint effort has eventually resulted in a tool that may perhaps be called unique in the world.

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a. 'Cone penetration test', pp. 55-67.
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c. 'The diving bell' — Annex 3, pp. 129-139.

laboratorium voor grondmechanica delft

delft soil mechanics laboratory

The Delft Soil Mechanics Laboratory (DSML) is a scientific consulting and research institute in the field of soil mechanics and foundation engineering.

DSML is a non-profit organization and forms together with the Delft Hydraulics Laboratory the foundation 'Stichting Waterbouwkundig Laboratorium'.

Staff and personnel: 300

Scope of activities:

Consulting Division

This Division handles assignments to solve soil mechanical and foundation engineering problems in connection with all types of civil engineering constructions and buildings. During construction guidance-services can be provided.

Some of the specializations are:

- prediction of bearing capacity of pile-foundations (tension and compression piles) including loading by negative skin friction and loading by horizontal forces either on the pile cap or the pile shaft;
- prediction of deformation characteristics of raft and pile foundations and similar constructions;
- prediction of settlements of all types of constructions such as roads, dikes, dams and hydraulic fills;
- evaluation of critical density of sands, for example in relation to the stability problem of underwater slopes;
- dynamic soil behaviour, for example during earthquakes;
- behaviour under cyclic loading conditions of marine structures, harbour works and transmission towers;
- evaluation and design of road and airfield pavements;
- slurry examinations;
- use of injection methods (sealing of permeable soil layers).

Research Division

The Group for General Soil Mechanics Research studies the fundamental behaviour of soil masses under different static and dynamic stress or strain conditions.

This work is mainly directed towards special foundation problems, such as:

- studies in the field of theoretical soil mechanics;
- behaviour of the foundation soil below offshore structures under wave load conditions;
- fundamental research related to dredging, processes such as cutting of soils and determination of stress-strain characteristics under fast deformation;
- loading tests on various constructions;
- model tests both in the institute and in the field.

The Group for Mathematics and Data Processing handles mathematical problems and develops computer programs. The Group has at its use up-to-date computer facilities like a Remote Batch Terminal giving access to several large computer-systems.

The Group for Rock Mechanics and Chemicophysical Research studies the correlation of mechanical properties of soil with chemical and physical phenomena of soil structure and the particles composing it.

Technical Division

Development and improvement of mechanical and electronic equipment for soil investigations, both in the field and in the institute, are carried out by the Technical Division.

Equipment

DSML has at its disposal all types of equipment necessary for execution of investigations in the field and for laboratory-testing of soil samples. The latter can be performed in temperature and humidity controlled rooms, when required.

Special equipment is available for dynamic triaxial testing of soil samples and for plane-strain tests.

Furthermore:

- CPT (cone penetration test) equipment with capacities up to 200 kN;
- continuous sampling apparatus capable of taking a continuous undisturbed soil sample up to a length of 20 metres with a diameter of 29 mm or 66 mm;
- probes for determination in situ of soil densities (electrical method for saturated sands, radio-active methods for other types of soil);
- pressuremeter, SPT and vane tests.
- a diving bell (2 men's crew) constructed for water depths up to 200 metres for investigations of the seabed (CPT-tests, density measurements, vane tests, continuous sampling with lengths up to 25 metres).
- various types of mechanical, pneumatic and electrical porewater pressure meters;
- equipment for CBR and plate bearing tests and for rolling tests to investigate pavement performance of roads and airfields;
- equipment for chemicophysical and mineralogical analyses of clays;

Publications

Apart from conference papers and publications in scientific journals DSML issues a free quarterly 'LGM-Mededelingen'.

Information will be sent on request.